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THE OIL HEATING ASSOCIATION OF CANADA CLEAN AIR PROGRAM PHASE I FACILITIES, TECHNIQUES AND PROCEDURES

by

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THE OIL HEATING ASSOCIATION OF CANADA CLEAN-AIR PROGRAM*

PHASE I: FACILITIES, TECHNIQUES AND PROCEDURES

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ABSTRACT

This report is the first in a series describing the results obtained in an investigation by the Canadian Combustion Research Laboratory and sponsored by the Oil Heating Association of Canada. The investigation has the prime objective of documenting the performance of available residential oil burning equipment in typical space and hot water heating applications in Canada. The report describes the program, facilities, measurement techniques, and test procedures developed for the investigation.

RÉSUMÉ

Ce rapport est le premier d'une série décrivant les résultats qu'on a obtenus pendant une enquête patronnée par l'Association canadienne de chauffage à l'huile et faite dans le Laboratorire canadien de recherche sur la combustion. L'enquête a pour l'objectif principal le documentation de la performance de l'équipement disponible et résidentiel de brûlage d'huile pour des applications typiques de chauffage d'espace et d'eau chaude au Canada. Ce rapport décrit le programme, les facilités, les techniques de mesure et les procédures d'essais qu'on a développées en vue de l'enquête.

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* Prepared for the Equipment and Service Committee of the Oil Heating Association of Canada, Chairman, C. S. James.

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CONTENTS

	Page
Abstract	i
Résumé	i
Contents	ii
Introduction	1
The Test Program	1
Test Furnaces	1
Test Burners	2
Firing Rates	2
Oil Stop Devices	2
Furnace Draft Conditions	3
Chimneys	3
Test Fuel	3
The Test Measurements	4
Furnace Installation	4
Measurement of Combustion Performance	4
Measurement of the Flue Gas Losses	6
Measurement of Thermal Efficiency	6
Measurement of Surface Temperature	6
Noise Measurements	9
The Test Procedure	9
Preparation	9
Test Measurements	10
Laboratory Results	12
References	14
Appendices	
A: Furnace Name Plate Data	15
B: Burner Name Plate Data	17

INTRODUCTION

In the summer of 1972 the Oil Heating Association of Canada (OHAC) requested the Canadian Combustion Research Laboratory to undertake a comparative evaluation of oil burning equipment currently available on the Canadian residential heating market. The objectives of the program were the charaterization of "good" and "bad" performance in terms of pollution potential and efficiency. This performance data might lead to the creation of requirements having expression as a voluntary industry standaid or being incorporated into the appropriate standards of the Canadian Standards Association. This report describes the test program, the facilities, the measurement techniques, and the test procedures used in this study.

THE TEST PROGRAM

Test Furnaces

The test program included measurements of the performance of two warm-air heaters, one hot-water heater, and one hot-water boiler under different draft conditions. Name plate data for the test furnaces is given in Appendix A.

Test Burners

Five burners were incorporated in the test program including those burners having the best performance based on the measurements made during an earlier series of screening trials in the small tunnel furnace(1).

The test burners were:

two flame-retention-head burners with 3450-rpm motors
two flame-retention-head burners with 1725-rpm motors
one standard-head burner with 1725-rpm motor

Name plate data for the test burners is quoted in Appendix B.

The burners selected for test will define the difference in performance than can be ascribed to the nature of the flame holding device (retention, swirl, or standard head) and to the different motor speeds (1725 and 3450 rpm). All the burners included in the program were recommended by the manufacturers for use with mechanical atomizers at firing rates of 0.65 to 1.00 US gph with alternate designs of retention head at the lower firing rates. The burners were not necessarily those recommended by the furnace manufacturer for use with their particular furnace.

Firing Rates

The program included burner tests at three firing rates: 0.5, 0.75, and 1.00 US gph. If this required a change in the retention head for one of the firing rates, the change was made in accordance with the manufacturers instructions. If the manufacturer permitted the use of two retention heads at any firing rate, the head appropriate to lower firing rate was used:

i.e. firing rate 0.5 - 0.75 US gph: Head AFC 1[1/]

0.75 - 1.25 US gph: Head AFC 2

The appropriate test heads would be:

0.5 - US gph AFC 1

0.75 - US gph AFC 1

1.00 - US gph AFC 2

Oil Stop Devices

None of the burners were supplied with an oil stop device (slip clutch or solenoid valve). The usefulness of this device in minimizing the smoke emission during start-up and shut-down periods had been demonstrated in previous experiments at CCRL. In the early part of this program all burners were tested with and without slip clutches to confirm this conclusion under operating conditions.

[1/] AFC is commercial terminology which identifies a particular design of burner retention head.

Furnace Draft Condition

The furnace draft conditions specified in the program were: minus 0.07; minus 0.02, and plus 0.05 inch of water (inch wg) with minus 0.02 inch wg nominated as the "standard" condition at which all burner adjustments were made. Neither the "standard" condition nor the alternative test condition are necessarily the draft condition recommended by the furnace manufacturer. The purpose of varying the furnace draft from the recommended setting was to establish the performance of the burner under abnormal conditions. The experimental furnace draft conditions selected were thought to be the extremes that might be encountered in practice.

Chimneys

The test furnaces were vented externally via 6-inch diam. natural draft "L-vent" chimneys. The stack height (furnace outlet to chimney top) was 30 ft and included two 45° bends. A barometric damper was incorporated in the flue system after the flue-gas measuring section.

Test Fuel

The fuel nominated for these tests was a special blend No. 2 fuel oil which did not conform to the usual furnace fuel-oil specification. The analysis of the oil is shown below(2).

TABLE 1

Special Blend No. 2 Fuel Oil

	API Gravity	27.9°
	Cloud Point	-4°F
	Pour Point	-30°F
Viscosity		
	SUV at 100°F	34.2 sec
	SUV at 122°F	32.6 sec
	Sulphur	0.26%
	Nitrogen	115 ppm
	Carbon	85.25%
	Hydrogen	12.26%
	Aromatics	70.6%
	Saturates	29.4%

The aromatic content of the fuel is high compared to a conventional No. 2 fuel oil; this is reflected in the carbon: hydrogen ratio of the fuel. Comparison of the results obtained with this fuel and conventional No. 2 fuel oil will indicate the influence of oil composition on smoke formation during combustion.

THE TEST MEASUREMENTS

Furnace Installation

The furnaces were sited on a refractory floor located within a wood panelled test-cell. The arrangement is illustrated in Figure 1. The purpose of this enclosure was primarily to provide similar acoustic enclosures for the two adjacent furnaces; it also served the purpose of eliminating any effect due to major drafts across the floor of the laboratory. The enclosure was 1-inch plywood on a 2 x 2-inch framework. The self-supporting panelled structure stood on a neoprene gasket on the concrete laboratory floor.

The air supply duct work, the exhaust duct work, and the chimney flue system and the measurement positions are shown schematically in Figure 2. The design of these systems are generally in agreement with the specifications of CSA. 140.4 "Oil-Fired Warm Air Furnaces"(3).

Measurement of Combustion Performance

The instrumentation for the tests consisted of conventional equipment for the measurement of furnace performance.

Gas Analysis

Component:	Method	
Carbon Dioxide) Carbon Monoxide) Hydrocarbons)	Non-Dispersive Infra-red.	
Oxygen	Paramagnetic	
Nitrogen Oxides	Chemi-Luminescent	
Smoke	Shell-Bacharach Meter:	Intermittent Measurement
	Von Brand Meter:	Continuous Measurement

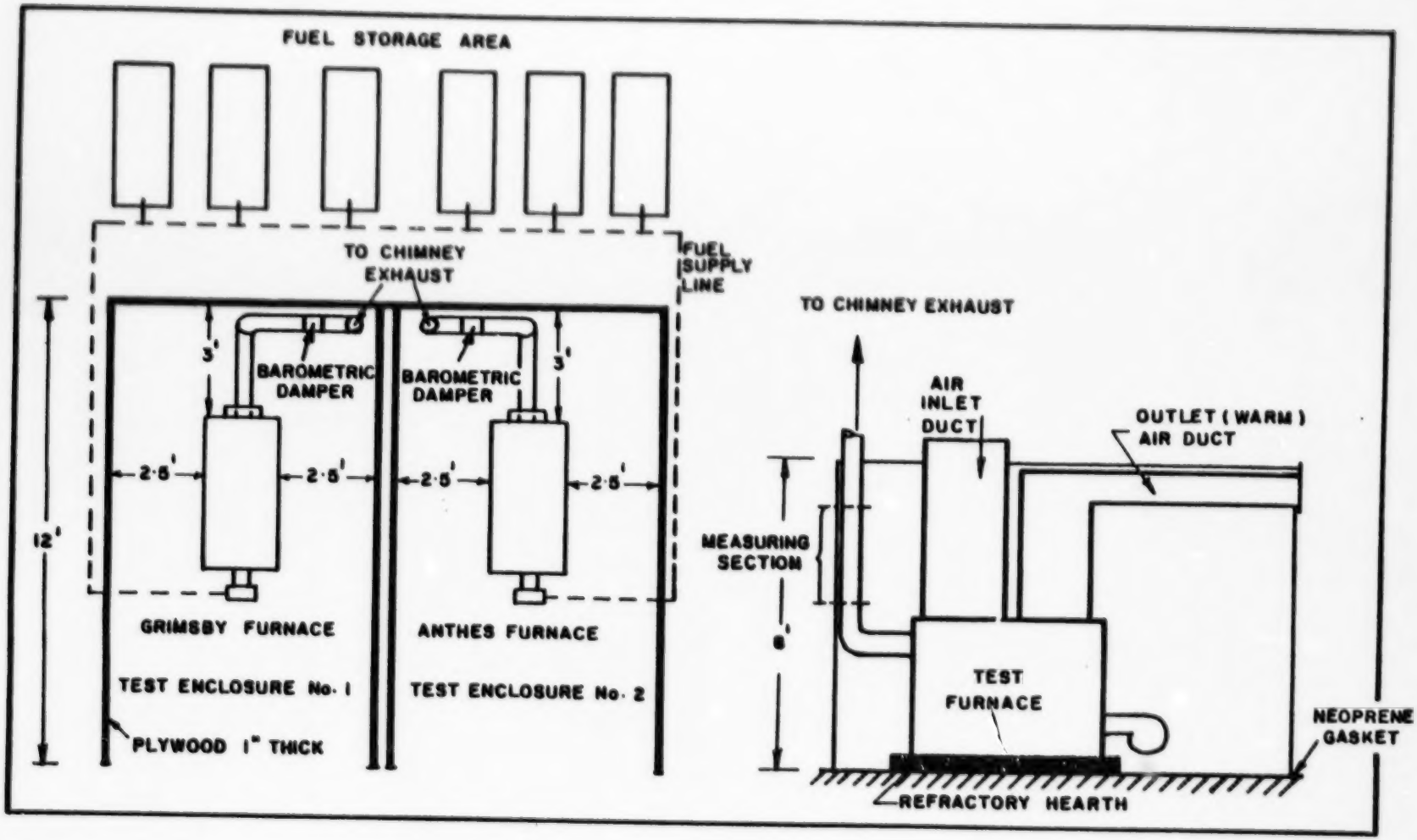

Figure 1. Arrangement of the test enclosures.

The intermittent smoke measurements were made during the adjustment of the burner at the standard draft condition of minus 0.02 inch wg and during the steady state operation. The continuous smoke measurements were made during the start-up and shut-down cycles.

Measurement of Flue Gas Losses

The flue gas temperature was measured by a network of five iron-constantan thermocouples located in the test section of the exhaust flue. The flue gas loss was calculated from these measurements, the known fuel analysis, and the flue gas analysis by the method described in CSA 140.0. "General Requirements for Oil Burning Equipment"(4).

The term commonly used to define the efficiency of units under test is combustion efficiency. This is defined as the percentage of the total heat input not lost in the flue gas.

Combustion Efficiency = 100 - (Flue Gas Loss %)

Measurement of Thermal Efficiency

The thermal efficiency of the system is defined as the heat transferred to the working medium(either hot water or air) during the steady-state operation of the system expressed as a percentage of the total heat input. This efficiency was calculated from measurements of the temperature rise of the working medium and its mass or volume flow rate. For warm air furnaces, the volume flow rate was calculated from measurements of air temperature and velocity at an eighteen-point network in the warm-air outlet duct. In the case of hot-water boilers the mass flow was measured with a calibrated rotameter.

Surface Temperatures

Surface temperatures on the outer casing of the unit were made at the locations illustrated in Figure 2.

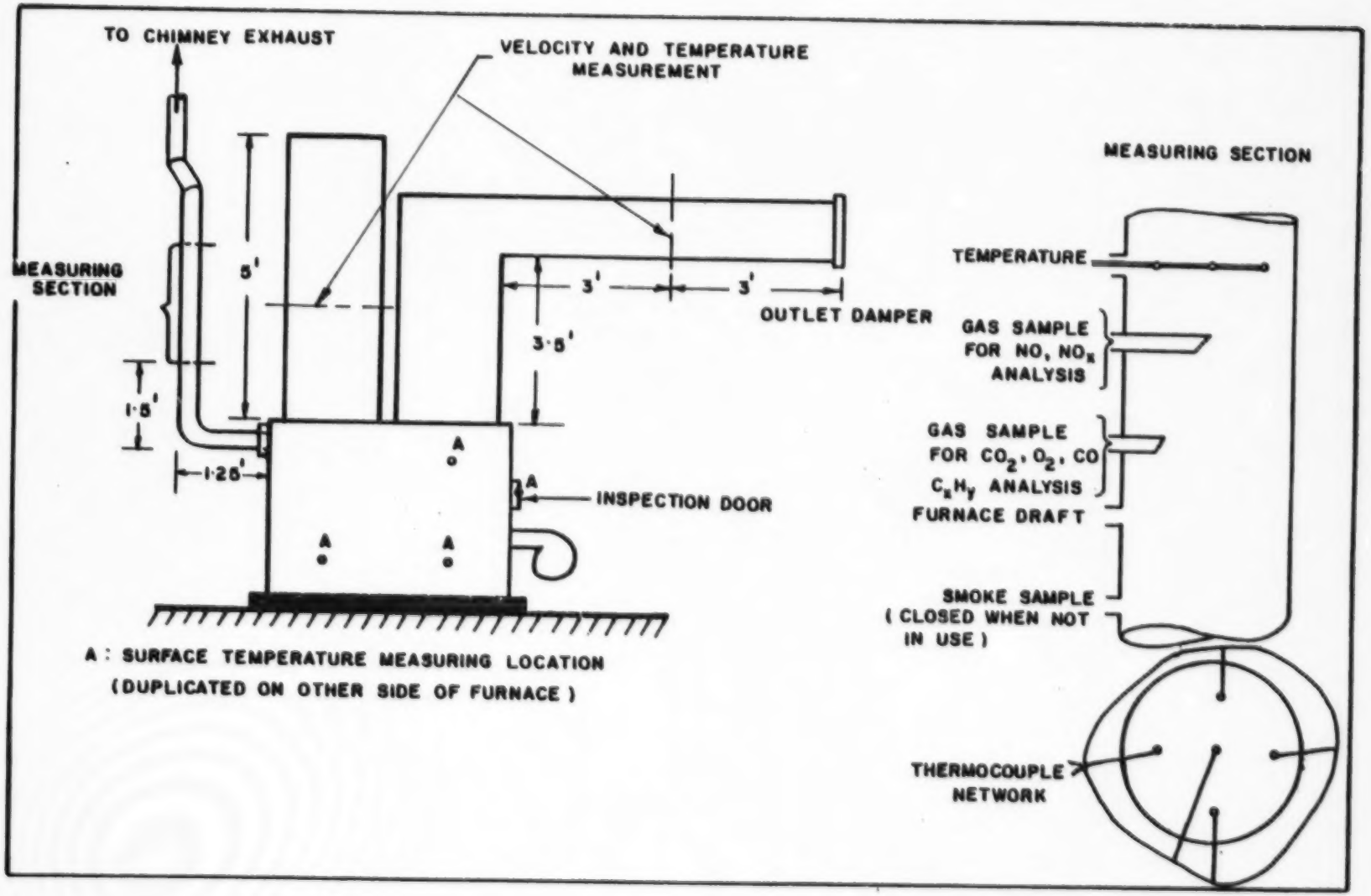

Figure 2. Flue gas and warm-air measuring positions.

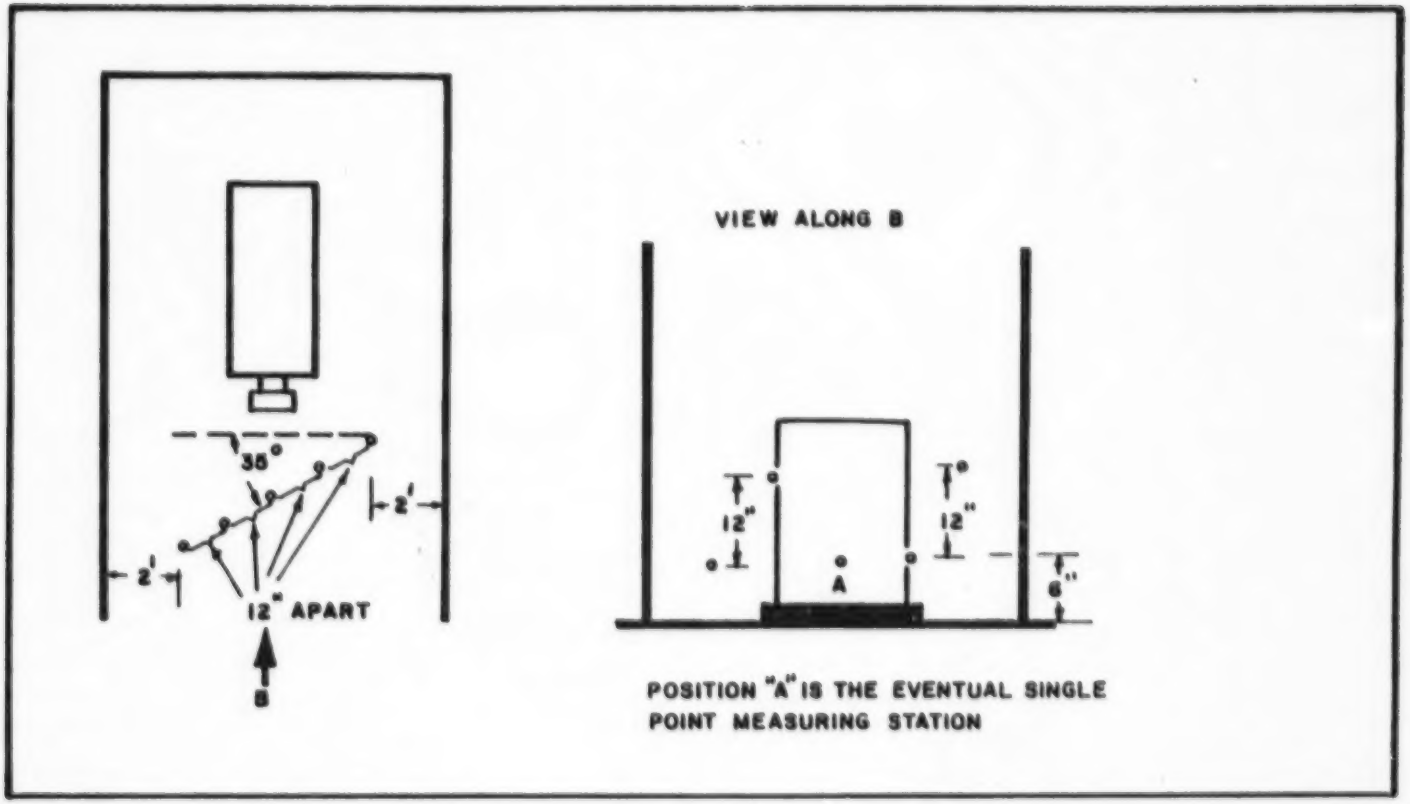

Figure 3. Noise measurement positions.

Noise Measurements

Measurements of the sound pressure level (SPL) in octave bands were initially made at the five positions shown in Figure 3. The measurements were made with a Bruel & Kjear precision sound level meter and octave filter set. It was observed that the difference in SPL at the five positions was less than 1 db in all cases and the number of measuring positions was reduced to one. This was located between 6 and 8 inches above the base and 3 feet from the motor shaft of the burner.

TEST PROCEDURE

Preparation

1. The furnace was installed on the refractory test bed; the burner and atomizing nozzle under test were assembled according to the manufacturers instructions and positioned in the combustion chamber.

2. The burner was ignited and allowed to achieve a steady combustion condition as indicated by CO_2 level and flue gas temperature. The barometric damper was adjusted to the reference draft condition(minus 0.02 inch wg).

3. If ignition was unsatisfactory, the electrode assembly was adjusted.

4. The warm air circulating fan was ajusted to give an air temperature rise of 85°F and the plenum pressure adjusted to plus 0.20 inch wg.

5. The air control to the burner was adjusted to give a maximum CO_2 concentration in the flue gas at a smoke number of 1 or less. (Experience indicated that it was extremely difficult to differentiate between smoke numbers 1 and 0).

Test Measurements

1. All continous measurement systems were switched on, calibrated, and kept in operation during the test.

2. The test was initiated by igniting the burner. At the instant of ignition a Shell-Bacharach smoke number measurement was started.

3. The duration of any transient concentration of carbon monoxide of hydrocarbon in the flue gas was recorded.

4. After the achievement of steady conditions, as indicated by constant flue gas temperature, constant air inlet and outlet temperatures and constant metal temperatures about one hour, a velocity traverse of the outlet warm air duct was made. The steady-state readings of gas analysis and temperature were all recorded.

5. All laboratory noise sources were eliminated and noise levels from the test unit were recorded.

6. The system was shut-down by switching off power to the burner. At the instant of shut-down, a Shell-Bacharach smoke number measurement was started.

7. After shut-down, all noise sources were eliminated and background noise levels in the laboratory were measured.

8. After the completion of the test procedure as described above two consecutive start, steady-run and shut-down cycles (10-min) were done to provide duplicate data on the transient start and shut-down performance.

9. The burner was re-ignited and allowed to achieve steady operation. The chimney draft was then altered to the next test condition (minus 0.07 inch wg) without adjustment to the burner. The test measurements were repeated at the new draft condition. This procedure was at the third draft condition (plus .05 inch wg) specified in the program.

Test Measurements (cont'd)

10. After these tests, the nozzle in the burner was removed, replaced with a different capacity test nozzle, and the test procedure was resumed at Stage 1 of preparation.

11. After the three firing rate tests (nominally 0.5, 0.75 and 1.00 gph), the burner was transferred to the second test furnace and the entire test procedure resumed at Stage 1 of preparation.

12. After these tests, the direct drive to the oil pump was replaced with a slip clutch, and the entire test procedure was resumed at Stage 1 of preparation.

A complete schedule of tests is illustrated in Table 2.

TABLE 2

Test Schedule For Burner A

Burner	Furnace	Oil Stop Devices [1]	Nominal Firing Rate US gph	Nominal Chimney Draft (inch wg)		
A	1	NO	0.5	-0.02	-0.07	+0.05
			0.75	"	"	"
			1.00	"	"	"
	2	NO	0.5	"	"	"
			0.75	"	"	"
			1.00	"	"	"
	1	YES	0.5	"	"	"
			0.75	"	"	"
			1.00	"	"	"
	2	YES	0.5	"	"	"
			0.75	"	"	"
			1.00	"	"	"

Total Number of Test Conditions 36

[1] It was deduced from the early test results, that the oil stop device had only a slight affect on the steady running conditions. The requirement to make steady-state observations without an oil stop device was therefore eliminated. This reduced the number of test conditions (steady state only) to 18. The start-up and shut-down measurements with and without oil stop devices were continued.

Laboratory Results

The experimental rest program was started in November 1972 and, at the time of writing, tests involving two furnaces, five burners, and three nozzles have been conducted. A laboratory data sheet is illustrated on page 13.

DATA SHEET: Oil Heating Association of Canada Program

Date: Test Furnace:

Fuel: Test Burner:

Oil Stop: Test Nozzle:

Flue Draft: Blast Tube Pressure:

Start Up											
Peak Concentrations			Duration of Peak								
Smoke	CO	C_xH_y	Smoke			CO			C_xH_y		
Steady Running Conditions											
Time to Achieve Steady Running:											
Combustion Gas Analysis %					Trace Gas Analysis ppm						
Smoke	CO_2	O_2	CO		NO		C_xH_y				
Temperature °F											
Air				Metal		Surface					
Flue	Inlet	Outlet	Peak	Min	Max	1	2	3	4	5	6
Shutdown											
Peak Concentration			Duration of Peak								
Smoke	CO	C_xH_y	Smoke			CO			C_xH_y		
Thermal Performance Btu/hr											
Fuel Input	Heat to Air		Stack Loss			Radiation					

Thermal Efficiency = ____ %

REFERENCES

1. Brown, T. D., "Some Performance Characteristics of Flame Retention Head Domestic Burners" Divisional Report FRC 72/8-CCRL Fuels Research Centre, Mines Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

2. Henderson, C., Special Projects Co-Ordinator, Gulf Oil Canada. Private Communication.

3. CSA Standard 140.4 1972"Oil-Fired Warm Air Furnaces"

4. CSA Standard 140.0 1972 "General Requirements for Oil Burning Equipment".

APPENDIX A: FURNACE NAME PLATE DATA

Anthes Eastern Limited: Warm-Air Furnace Ceramic-Fibre Combustion Chamber Furnace Model: LOD 115				
Input Btu/hr	140,000	119,000	105,000	91,000
Output Btu/hr	112,000	93,000	82,000	72,000
Nozzle Specification	80°NS	80°NS	80°NS	80°NS
Firing Rate US gph	1.00	0.85	0.75	0.65
Blower Motor (hp)	1/3	1/3	1/3	1/3
Design Static Pressure:	0.25	0.25	0.25	0.25
Flue Diameter Inches	7	7	7	7
Recommended Burner	Anthes 55J01D103	Anthes 55J01D103	Anthes 55J01D103	Anthes 55J01D103

Grimsby Stove & Furnaces Ltd: Warm-Air Furnace Stainless-Steel Combustion Chamber: Furnace Model: 67-117C	
Input Btu/hr	Not quoted. (140,000)
Output Btu/hr	Max 117,000 Min 117,000
Nozzle Specification	80°Special Solid
Firing Rate US gph	Max 1.00 Min 1.00
Blower Motor	Not quoted.
Design Static Pressure: "H_2O	Not quoted.
Flue Diameter	Not quoted.
Recommended Burner	Aero CGF 1

APPENDIX A: FURNACE NAME PLATE DATA

American Standard Hot-Water Boiler

Stell Combustion Chamber

Model No: 1340

Input	Max: - 230,000
Output	Max: - 169,000
Firing Rate	Max: 1.5
Nozzle Specification	70° Hollow or 70° Special Solid
Flue Diameter (Inches)	9
Recommended Burner	D. H. Burner

APPENDIX B: BURNER NAME PLATE DATA

Burner Type	Retention Head				Standard Head**	
Manufacturer	Beckett	Aero	Aero	Anthes	Terry	Beckett
Model No:	AF	F-AFC-208	F-AFC-208	55J01D103	A1	S
Motor						
Speed (rpm)	3450	3450	1725	1725	1725	1725
Horsepower	1/7	1/8	1/8	1/8	1/8	1/8
Firing Range US gph	0.5-3.0*	0.75-2.00*	0.5-1.75*	0.65-1.00	0.75-1.25	0.5-3.0
Nozzle Type	80°	80°	80°	N.S.	N.S.	70° Solid
Oil Pump	Sundstrand	Inglis	Inglis	Inglis	Inglis	Inglis
Model	A2VA-7016	J3-C6-100-3	J2-CB-100-3	J2-CB-100-3	J3-CB-200-3	J2-BB-300-3

** At the time of writing the standard head burner to be tested had not been selected.

* These burners require different retention heads to cover the firing range quoted.

NS = Not specified.